

**WHAT IS CLAIMED IS:**

1. A catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system comprising plural mirrors, wherein a second mirror from the image surface through the optical path receives convergent pencil of rays, and has a paraxial magnification of  $-0.14$  or smaller.

10

2. A catoptric projection optical system according to claim 1, wherein said catoptric projection optical system includes six or more mirrors.

15

3. A catoptric projection optical system according to claim 1, wherein a third mirror from the image surface through the optical path has the largest effective diameter among the plural mirrors.

20

4. A catoptric projection optical system according to claim 1, wherein all of the plural mirrors are aspheric mirrors including a multilayer coating that reflect light having a wavelength of  $20\text{ nm}$  or smaller.

25

5. A catoptric projection optical system according to claim 1, wherein said catoptric projection

optical system projects light from a reflection mask that is arranged on the object surface.

6. A catoptric projection optical system  
5 according to claim 1, wherein said catoptric projection optical system is non-telecentric at a side of object surface.

7. A catoptric projection optical system  
10 according to claim 1, wherein said plural mirrors form an intermediate image.

8. A catoptric projection optical system  
according to claim 7, wherein the intermediate image  
15 does not accord with a surface of one of the plural mirrors.

9. A catoptric projection optical system  
according to claim 1, wherein all of said plural  
20 mirrors are arranged between the object surface and the image surface.

10. A catoptric projection optical system  
according to claim 1, wherein the second mirror from  
25 the image surface through the optical path has a paraxial magnification between -30 and -0.4.

11. A catoptric projection optical system  
according to claim 1, wherein an angle between two  
marginal rays of said convergent pencil of rays is  $9^\circ$   
or greater in meridional plane, when said catoptric  
5 projection optical system has a numerical aperture of  
0.25.

12. A catoptric projection optical system for  
projecting a pattern on an object surface onto an image  
10 surface, said catoptric projection optical system  
comprising plural mirrors, wherein a second mirror from  
the image surface through the optical path receives  
convergent pencil of rays, and an angle between two  
marginal rays of said convergent pencil of rays is  $3^\circ$   
15 or greater in meridional plane when said catoptric  
projection optical system has a numerical aperture of  
0.25 or greater.

13. A catoptric projection optical system  
20 according to claim 12, wherein said catoptric  
projection optical system includes six or more mirrors.

14. A catoptric projection optical system  
according to claim 12, wherein a third mirror from the  
25 image surface through the optical path has the largest  
effective diameter among the plural mirrors.

15. A catoptric projection optical system  
according to claim 12, wherein all of the plural  
mirrors are aspheric mirrors including a multilayer  
coating that reflect light having a wavelength of 20 nm  
5 or smaller.

16. A catoptric projection optical system  
according to claim 12, wherein said catoptric  
projection optical system projects light from a  
10 reflection mask that is arranged on the object surface.

17. A catoptric projection optical system  
according to claim 12, wherein said catoptric  
projection optical system is non-telecentric at a side  
15 of object surface.

18. A catoptric projection optical system  
according to claim 12, wherein said plural mirrors form  
an intermediate image.

20

19. A catoptric projection optical system  
according to claim 18, wherein the intermediate image  
does not accord with a surface of one of the plural  
mirrors.

25

20. A catoptric projection optical system  
according to claim 12, wherein all of said plural

mirrors are arranged between the object surface and the image surface.

21. A catoptric projection optical system  
5 according to claim 12, wherein the second mirror from the image surface through the optical path has a paraxial magnification between -30 and -0.14.

22. A catoptric projection optical system  
10 according to claim 12, wherein the angle between two marginal rays of said convergent pencil of rays is  $9^\circ$  or greater in meridional plane, when said catoptric projection optical system has a numerical aperture of 0.25.

15

23. A catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system comprising six mirrors that include, in order from the  
20 object surface to the image surface on an optical path, a first mirror, a second mirror, a third mirror, a fourth mirror, a fifth mirror, and a sixth mirror to sequentially reflect light,

wherein the first mirror has a convex or  
25 plane shape, and the fifth mirror receives convergent pencil of rays.

24. A catoptric projection optical system according to claim 23, wherein the fifth mirror has a paraxial magnification of -0.14 or smaller.

5        25. A catoptric projection optical system according to claim 23, wherein an angle between two marginal rays of said convergent pencil of rays is  $3^\circ$  or greater in meridional plane when said catoptric projection optical system has a numerical aperture of  
10    0.25 or greater.

26. A catoptric projection optical system according to claim 23, wherein said six mirrors form an intermediate image.

15

27. A catoptric projection optical system according to claim 26, wherein the intermediate image does not accord with a surface of one of the six mirrors.

20

28. A catoptric projection optical system according to claim 23, wherein all of six mirrors are arranged between the object surface and the image surface.

25

29. A catoptric projection optical system according to claim 23, wherein the second mirror from

the image surface through the optical path has a paraxial magnification between -30 and -0.4.

30. A catoptric projection optical system  
5 according to claim 23, wherein the fifth mirror has a paraxial magnification between -30 and -0.4.

31. A catoptric projection optical system  
according to claim 23, wherein an angle between two  
10 marginal rays of said convergent pencil of rays is  $9^\circ$  or greater in meridional plane, when said catoptric projection optical system has a numerical aperture of 0.25.

15 32. A catoptric projection optical system according to claim 23, wherein said catoptric projection optical system includes, in order of from the object surface to the image surface, the second mirror, the first mirror, the fourth mirror, the sixth  
20 mirror, the third mirror and the fifth mirror, wherein an intermediate image is formed between the fourth and third mirrors.

33. A catoptric projection optical system  
25 according to claim 32, wherein the intermediate image is formed between the fourth and sixth mirrors.

34. A catoptric projection optical system according to claim 32, wherein the intermediate image is formed between the six and third mirrors.

5           35. An exposure apparatus comprising:

          a catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system comprising plural mirrors, wherein a second mirror from  
10 the image surface through the optical path receives convergent pencil of rays, and has a paraxial magnification of  $-0.14$  or smaller;

          a mask stage that supports a mask having the pattern, and positions the pattern on the mask onto the  
15 object surface;

          a wafer stage that supports an object having a photosensitive layer, and positions the photosensitive layer on the image surface; and

          a mechanism for synchronously scanning said  
20 mask stage and said wafer stage while the mask is illuminated by light having a wavelength of  $20\text{ nm}$  or smaller.

36. An exposure apparatus comprising:

25           a catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system



comprising plural mirrors, wherein a second mirror from the image surface through the optical path receives convergent pencil of rays, and an angle between two marginal rays of said convergent pencil of rays is  $3^{\circ}$

5 or greater in meridional plane when said catoptric projection optical system has a numerical aperture of 0.25 or greater;

a mask stage that supports a mask having the pattern, and positions the pattern on the mask onto the  
10 object surface;

a wafer stage that supports an object having a photosensitive layer, and positions the photosensitive layer on the image surface; and

a mechanism for synchronously scanning said  
15 mask stage and said wafer stage while the mask is illuminated by light having a wavelength of 20 nm or smaller.

37. An exposure apparatus comprising:

20 a catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system comprising six mirrors that include, in order from the object surface to the image surface, a first mirror, a  
25 second mirror, a third mirror, a fourth mirror, a fifth mirror, and a sixth mirror to sequentially reflect light, wherein the first mirror has a convex or plane

shape, and the fifth mirror receives convergent pencil of rays;

a mask stage that supports a mask having the pattern, and positions the pattern on the mask onto the  
5 object surface;

a wafer stage that supports an object having a photosensitive layer, and positions the photosensitive layer on the image surface; and

a mechanism for synchronously scanning said  
10 mask stage and said wafer stage while the mask is illuminated by light having a wavelength of 20 nm or smaller.

38. An exposure apparatus comprising:

15 an illumination optical system for illuminating a pattern with light from a light source; and

a catoptric projection optical system for projecting a pattern on an object surface onto an image  
20 surface, said catoptric projection optical system comprising plural mirrors, wherein a second mirror from the image surface through the optical path receives convergent pencil of rays, and has a paraxial magnification of -0.14 or smaller.

25

39. An exposure apparatus according to claim 38,  
wherein said projection optical system projects light  
reflected on the pattern, onto the image surface.

5           40. An exposure apparatus comprising:  
            an illumination optical system for  
illuminating a pattern with light from a light source;  
and

            a catoptric projection optical system for  
10 projecting a pattern on an object surface onto an image  
surface, said catoptric projection optical system  
comprising plural mirrors, wherein a second mirror from  
the image surface through the optical path receives  
convergent pencil of rays, and an angle between two  
15 marginal rays of said convergent pencil of rays is  $3^\circ$   
or greater in meridional plane when said catoptric  
projection optical system has a numerical aperture of  
0.25 or greater.

20           41. An exposure apparatus according to claim 40,  
wherein said projection optical system projects light  
reflected on the pattern, onto the image surface.

            42. An exposure apparatus comprising:  
25           an illumination optical system for  
illuminating a pattern with light from a light source;  
and

a catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system comprising six mirrors that include, in order from the object surface to the image surface, a first mirror, a second mirror, a third mirror, a fourth mirror, a fifth mirror, and a sixth mirror to sequentially reflect light, wherein the first mirror has a convex or plane shape, and the fifth mirror receives convergent pencil of rays.

43. An exposure apparatus according to claim 42, wherein said projection optical system projects light reflected on the pattern, onto the image surface.

15

44. A device fabricating method comprising the steps of:

exposing an object using an exposure apparatus; and

20 developing the object that has been exposed, wherein said exposure apparatus includes:

an illumination optical system for illuminating a pattern with light from a light source; and

25 a catoptric projection optical system for projecting a pattern on an object surface onto an image surface, said catoptric projection optical system

comprising plural mirrors, wherein a second mirror from the image surface through the optical path receives convergent pencil of rays, and has a paraxial magnification of  $-0.14$  or smaller.